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# EXPERIMENTAL RESISTIVITY ELECTRODE EMPLACEMENT

# FOR THE HAWAII GEOTHERMAL PROJECT

Presented by

G. E. Brandvold, Exploratory Projects Department, 5710, Sandia Laboratories, to the U. S. - Japan Cooperative Science Seminar on "Utilization of Volcano Energy", held in Hilo, Hawaii, February 4-8, 1974

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## ABSTRACT

Sandia Laboratories' expertise in earth-penetrating projectiles has been applied to problems of geothermal resource research. Field trials of an experimental terradynamics electrode for resistivity surveys have been carried out in cooperation with the Hawaii Institute of Geophysics, and the design of an instrumented magma penetrometer begun.

# EXPERIMENTAL RESISTIVITY ELECTRODE EMPLACEMENT FOR THE HAWAII GEOTHERMAL PROJECT

## Introduction

Sandia Laboratories is conducting a program of research directed toward utilization of energy from magma sources[1], and also has developed an expertise in the dynamics of earth-penetrating projectiles (Terradynamics)[2]. These interests were recently combined in two experimental projects. The first, performed in cooperation with the Hawaii Institute of Geophysics, consisted of the emplacement of experimental earth-penetrating resistivity electrodes at 15 sites on the island of Hawaii. The second was the design of a magma penetrator instrumented to measure viscosity and temperature as a function of depth in a surface magma pool.

## Resistivity Electrode

The University of Hawaii, sponsored by NSF-RANN[3], Hawaii State and Hawaii County, is studying the geothermal potential of Hawaii Island. Geoelectric surveys, using a deep-sounding long-wire source and roving loop receiver, required emplacement of several sets of electrodes with contact resistances less than 100 ohms. It is difficult to achieve good electrical grounds in Hawaii Island since

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[1] Young, C. W., A Proposal to Investigate a New Energy Source: The Direct Magma Tap, SLA-73-0850, January 1974

[2] Young, C. W., The Development of Empirical Equations for Predicting Depth of an Earth Penetrating Projectile, SCDR 67-60, May 1967

[3] NSF Grant, GI38319

the surface layers consist largely of basaltic lava flows often with none to a few inches of overburden. In addition, the terrain often prevents access for power-operated equipment to assist site preparation for electrodes.

Because of complementary interests in studying volcanic energy, Sandia Laboratories examined this problem and suggested that implants of air-dropped electrodes might provide both greater depths of penetration[4], tighter contact between metal and earth, and easy emplacement in difficult terrains. Accordingly, a minimum-cost electrode as shown in Figure 1 was designed using solid low-carbon steel for the main body with a separating finned afterbody. This afterbody, connected to the main penetrator by an electrical cable, was designed to stay at the surface to enable attachment of an electrical current source. These electrodes cost about $60 in quantities of 100 or so. In December 1973, 29 electrodes were dropped at the 15 site locations of Table 1. Figure 2 shows the approximate map locations of these drop points. The film clip illustrated the field operation. The drop aircraft is guided to the drop area by one observer located on the flight line who directs the pilot by radio to fly toward him. A second observer at right angles to the flight line tells the pilot when to drop. A small aircraft such as the "Beaver" is quite adequate; the larger aircraft used in Hawaii was more convenient. Sandia teams experienced in this drop technique achieve an emplacement accuracy of about 10% of the drop altitude; for the desired electrode impact velocity of 130 m/sec, this equaled about 75 meters. Two penetrators were not

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[4]Tagy, G. F., Earth Resistances, Pitman Publ. Corp., 1964, 258 p.

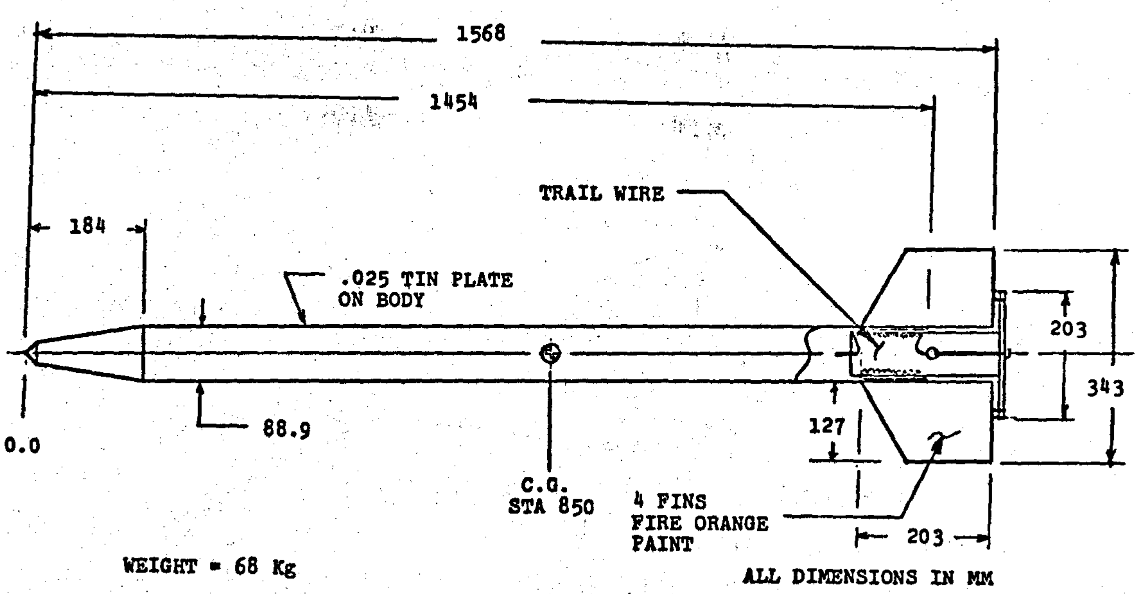
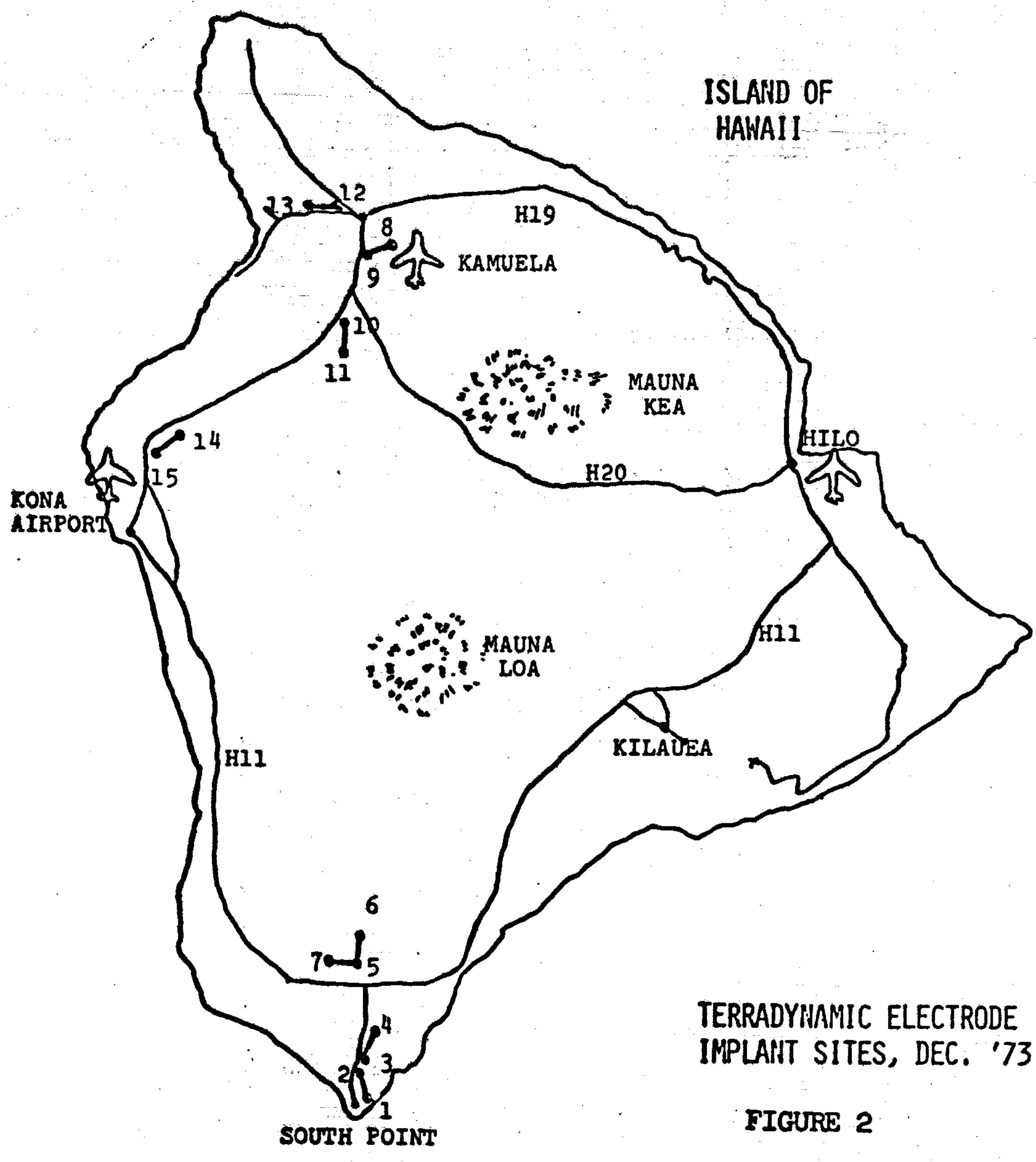



FIGURE 1: TERRADYNAMIC ELECTRODE

Table 1. Electrode Site Coordinates

| Site No. | North Latitude | West Longitude |
|---|---|---|
| | **SOUTH POINT** | |
| 1 | 18° 57.57M | 155° 41.01M |
| 2 | 18° 57.83M | 155° 40.18M |
| 3 | 18° 59.58M | 155° 38.88M |
| 4 | 19° 00.24M | 155° 39.34M |
| 5 | 19° 04.69M | 155° 41.09M |
| 6 | 19° 05.53M | 155° 41.44M |
| 7 | 19° 04.72M | 155° 41.71M |
| | **KAMUELA** | |
| 8 | 19° 59.24M | 155° 39.65M |
| 9 | 19° 58.42M | 155° 39.72M |
| 10 | 19° 53.60M | 155° 41.94M |
| 11 | 19° 52.89M | 155° 42.38M |
| 12 | 20° 01.85M | 155° 44.05M |
| 13 | 20° 01.70M | 155° 44.93M |
| | **KONA** | |
| 14 | 19° 47.48M | 155° 51.30M |
| 15 | 19° 46.79M | 155° 51.73M |




TERRADYNAMIC ELECTRODE
IMPLANT SITES, DEC. '73

FIGURE 2

found due to heavy foliage, and two experienced broken electrical wires. The remaining 25 were successfully emplaced to depths of 2 to 6 meters. Preliminary resistance measurements showed resistances less than 200 ohms per electrode (100 ohms per pair) except at sites 5, 6 and 7, where approximately 1500 ohms was observed. This area is in the 1868 lava flow with no overburden. Study of further lowering of resistance by treating implanted electrodes with conductive "mud" is continuing.

## Magma Penetrometer

Sandia Laboratories has designed and successfully emplaced instrumented probes in unconsolidated soils and marine sediments, in rocks such as welded tuffs, sandstones and granites, in permafrost, and in sea ice. The study of magma properties offered a new opportunity for applying this technology.

Figure 3 shows a "first-generation" magma penetrometer which has been fabricated and is on-the-shelf awaiting an appropriate test opportunity. Designed to be dropped from a helicopter (to achieve accuracy) and parachute-retarded to about 20 m/sec entry velocity, the probe contains 3 accelerometers, 2 radiometers and 2 tip thermocouples. A radio transmits through the trailing antenna which will survive the few seconds of magma heating. Figure 4 is a concept for a "second-generation" penetrometer which we propose to develop if laboratory studies of magma properties indicate in situ data is necessary. This design, patterned after a successful ice penetrator, would use a separable antenna housing and stored umbilical line to enable higher velocity delivery for magma pool crust penetration. At least 30 meters of data recording depth is envisaged.

Tests of the sensor elements of these probes have been performed at magma temperatures in the laboratory, but field trials remain to be done.

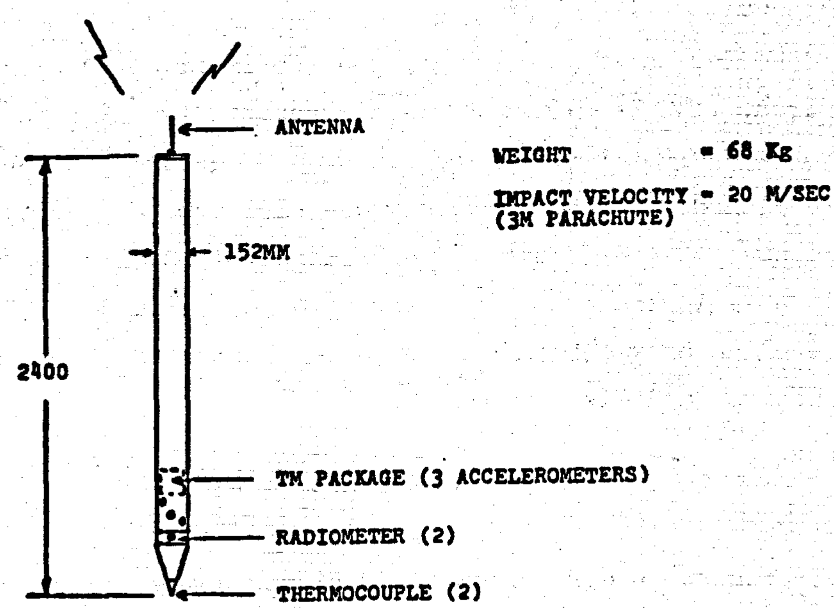



FIGURE 3: MAGMA PENETROMETER

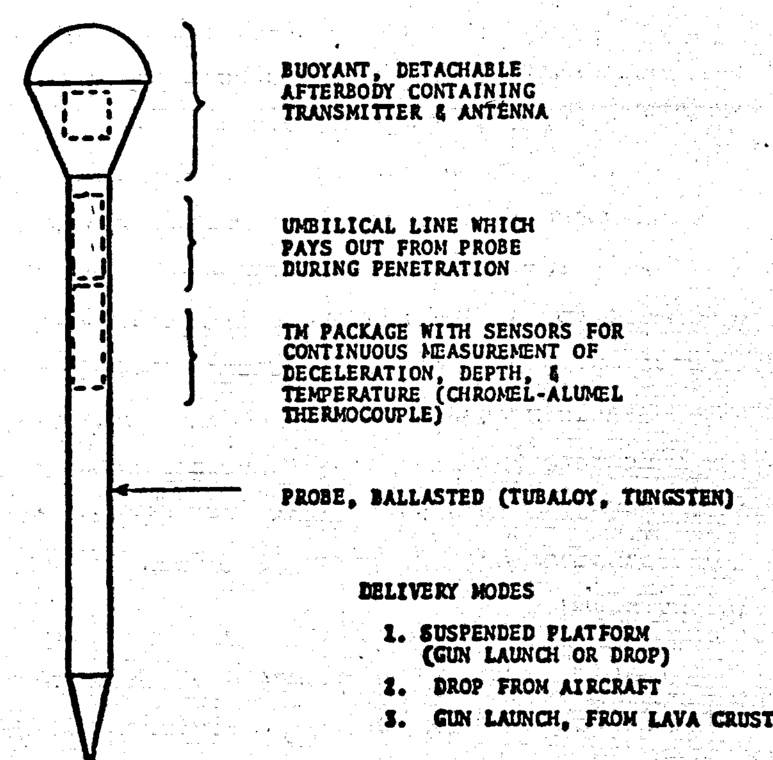



FIGURE 4: PROPOSED MAGMA PENETROMETER CONFIGURATION

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